294623 Intake
R4-NC-Brunswick

Brunswick Nuclear Plant

CP&L

1996 Environmental Monitoring Report

Environmental Services Section

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Metric-English Conversion and Units of Measure

Length

1 micron (μm) = 4.0 x 10^{-5} inch
1 millimeter (mm) = 1000 m = 0.04 inch
1 centimeter (cm) = 10 mm = 0.4 inch
1 meter (m) = 100 cm = 3.28 feet
1 kilometer (km) = 1000 m = 0.62 mile

Volume

1 milliliter (ml) = 0.034 fluid ounce
1 liter = 1000 ml = 0.26 gallon
1 cubic meter = 35.3 cubic feet

1228.4 cfs

Area

1 square meter (m^2) = 10.76 square feet
1 hectare (ha) = 10,000 m^2 = 2.47 acres

Weight

1 microgram (μg) = 10^{-3} mg or 10^{-6} g = 3.5 x 10^{-8} ounce
1 milligram (mg) = 3.5 x 10^{-5} ounce
1 gram (g) = 1000 mg = 0.035 ounce
1 kilogram (kg) = 1000 g = 2.2 pounds
1 metric ton = 1000 kg = 1.1 tons
1 kg/hectare = 0.89 pound/acre

Temperature

Degrees Celsius (°C) = 5/9 (°F-32)

Common and Scientific Names of Species Used in This Report

Atlantic stingray	*Dasyatis sabina*	Gobies	*Gobiosoma* spp.
Shrimp eel	*Ophichthus gomesi*	Atlantic cutlassfish	*Trichiurus lepturus*
Atlantic menhaden	*Brevoortia tyrannus*	Southern flounder	*Paralichthys lethostigma*
Anchovies	*Anchoa* spp.	Tonguefish	*Symphurus spp.*
Spotted hake	*Urophycis regius*	Blackcheek tonguefish	*S. plagiusa*
Bay anchovy	*A. mitchilli*	Shrimp	*Penaeus* spp.
Pinfish	*Lagodon rhomboides*	Brown shrimp	*P. aztecus*
Silver perch	*Bairdiella chrysura*	Pink shrimp	*P. duorarum*
Weakfish	*Cynoscion regalis*	White shrimp	*P. setiferus*
Spot	*Leiostomus xanthurus*	Swimming crab larvae	Portunid megalops
Star drum	*Stellifer lanceolatus*	Blue crabs	*Callinectes* spp.
Croaker	*Micropogonias undulatus*	Blue crab	*C. sapidus*

Executive Summary

Biological monitoring of the Cape Fear Estuary at Carolina Power & Light Company's Brunswick Nuclear Plant (BNP) was conducted in 1996 as part of the National Pollutant Discharge Elimination System permit requirements. Monitoring results from 1996 were compared to those of previous years. Entrainment and impingement studies monitored the effectiveness of the intake modifications in reducing entrainment and impingement of fish and shellfish.

Impingement study results indicated that the dominant larva impinged was croaker, while the dominant juvenile impinged was bay anchovy. Spot was the dominant larval organism entrained. With the intake screens on slow rotation, the overall survival estimate for selected larvae returned to the estuary was 18% (excluding *Anchoa* spp. ≥ 13 mm). Survival estimates for larvae of the most valuable commercial species, shrimp and blue crabs, were 80% and 86%, respectively. The survival estimate for all juvenile and adult species combined was 66% (excluding bay anchovy). As with the larvae, juvenile and adult shrimp and blue crabs exhibited the highest survival rates ranging from 87% to 92%. Entrainment and larval impingement comparisons indicated that utilization of fine-mesh screens reduced entrainment of larvae by approximately 2% to 56% depending upon species present and season. Impingement data showed that eight out of eleven taxa (including total organisms) of juvenile and adult fish and shellfish exhibited significant decreases in impingement densities after the installation of the diversion structure in 1983.

Biological monitoring during 1996 continued to show that the combination of flow minimization, fine-mesh screens, and diversion structure effectively reduced the number of entrained and impinged fish and shellfish. These modifications also continued to ensure that the most valuable commercial species are returned alive to the estuary in large numbers.

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1.0 INTRODUCTION

Carolina Power & Light Company (CP&L) was issued a permit in December 1974 to discharge cooling water from the Brunswick Nuclear Plant (originally called the Brunswick Steam Electric Plant) into the Atlantic Ocean under the National Pollutant Discharge Elimination System (NPDES). Cooling water is withdrawn from the Cape Fear River (CFR). As a stipulation of the NPDES permit, biological monitoring is required to provide sufficient information for a continuing assessment of power plant impacts on the Cape Fear Estuary (CFE) with particular emphasis on the marine and estuarine fisheries.

A stipulation of the 1981 NPDES permit and subsequent permits was the implementation of power plant modifications to reduce entrainment and impingement of estuarine organisms resulting from the intake of cooling water. A permanent diversion structure was constructed across the mouth of the intake canal in November 1982 to reduce impingement by preventing large fish and shellfish from entering the intake canal (Figure 1.1). To reduce entrainment, two fine-mesh (1-mm) screens were installed on each unit in July 1983 and a third was installed on each unit in April 1987. Presently three of the four intake traveling-screen assemblies on each unit are covered with fine mesh screens.

Under the current permit, a maximum intake flow of 26.1 cubic meters per second (cms) per unit is allowed from December through March, and 31.1 cms per unit is allowed from April through November. Normally only fine-mesh screens are used during these periods of maximum intake flow. The flow of one unit may be increased to 34.8 cms during July, August, and/or September by using a fourth intake pump operating with coarse-mesh (9.4-mm) screens.

Beginning in 1994, Carolina Power & Light Company reduced the biological monitoring program with the concurrence of the North Carolina Department of Environment, Health & Natural Resources. Because of almost two decades of operation with no adverse impact on fish and shellfish populations in the Cape Fear Estuary, the monitoring program was modified to concentrate on the impingement and entrainment of organisms (Figure 1.2). This report presents data on impingement and entrainment rates of larval, juvenile, and adult fish and shellfish and evaluates the effectiveness of the NPDES-required plant intake modifications.

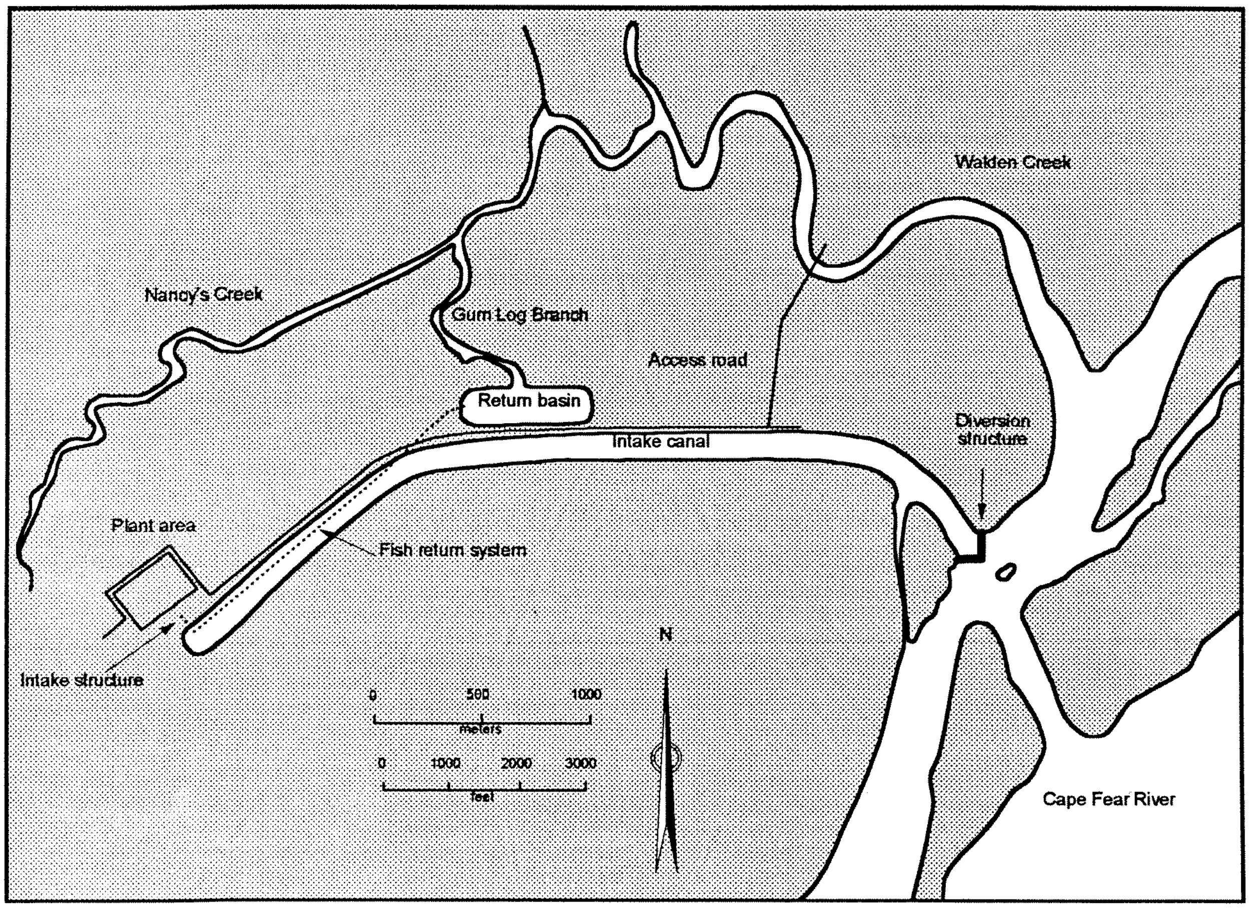

Figure 1.1 **Location of fish diversion structure, fish return system, and return basin at the Brunswick Nuclear Plant.**

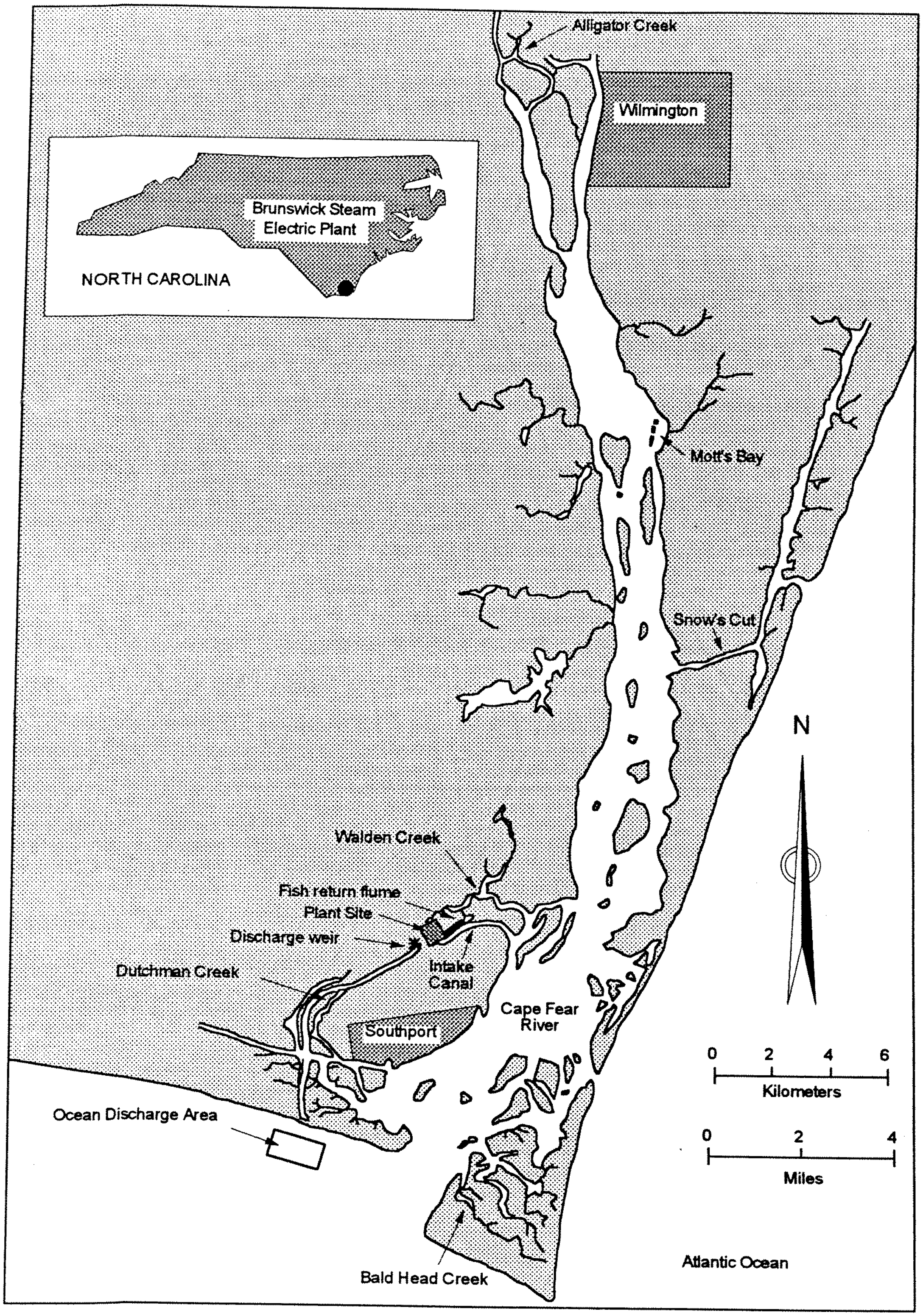

Figure 1.2 Brunswick Nuclear Plant biological monitoring program sampling stations for 1996.

2.0 MONITORING PROGRAM RESULTS

2.1 Introduction

Past data indicated that the impingement of large fish and shellfish has been reduced as a result of the 9.4-mm mesh screening on the diversion structure (CP&L 1984, 1985a, 1985b). Organisms small enough to enter the intake canal through the diversion structure may be affected by plant operations in one of two ways: (1) they may be impinged on the plant intake screens and returned to the Cape Fear Estuary (CFE) via a flume and return basin or (2) they may be entrained through the plant. Previous studies by CP&L have also shown a reduction in the entrainment of small organisms due to installation of fine-mesh screens at the intake structure.

Entrainment sampling during 1996 documented the species composition, seasonality, and abundances of larval and postlarval organisms passing through the cooling system. Larval impingement sampling evaluated the success of the fine-mesh screens in reducing entrainment of this life stage of organisms. Juvenile and adult (J/A) impingement sampling documented species composition, densities, weights, and sizes of juvenile and adult organisms impinged during 1996. This sampling also provided evidence of the continued effectiveness of the diversion structure. Survival study results from previous years were used to determine the effectiveness of the return system at returning impinged organisms alive to the CFE (CP&L 1988).

2.2 Methods

The collection gear for entrainment and impingement has remained unchanged since 1984 (CP&L 1985a). Because sampling was conducted only once per month during 1996, results were not expanded to obtain annual estimates of organisms entrained or impinged; rather, entrainment and impingement rates, densities, and total number collected were expanded to give an estimate for 24 hours. The juvenile and adult impingement program included fish and shrimp ≥ 41 mm, portunid crabs ≥ 25 mm, and eels and pipefish ≥ 101 mm. Individuals smaller than these limits were included in the larval impingement program.

The densities calculated for all larval organisms from samples collected per sampling date were averaged to obtain a mean number per 1000 m^3 of water entrained through the plant. Densities for juvenile and adult organisms impinged on each sampling date were calculated by dividing the total number of organisms collected by the volume of water pumped through the plant. Densities were expressed as the number per million cubic meters of water pumped through the plant during each 24-hour sampling period.

Time-series analysis was performed on juvenile and adult impingement data (ln [density + 1]) (CP&L 1985a). Selected species included bay anchovy, Atlantic menhaden, croaker, spot, weakfish, southern flounder, brown shrimp, pink shrimp, white shrimp, and blue crabs (*Callinectes* spp.). Data were analyzed from January 1977 through December 1996. Data from 1983 were excluded from the analysis because impingement samples were not collected during July through December of that year. One sampling trip per month was used for all years for comparable sampling effort.

2.3 Results and Discussion

2.3.1 Dominant Species

Spot was the most abundant organism collected in entrainment samples during 1996 and comprised 39.0% of the cumulative density of all organisms collected (Table 2.1). Croaker (14.7%) was the second most abundant followed by *Anchoa* spp. (<13 mm) and *Anchoa* spp. (≥ 13 mm) (10.6% and 8.8%, respectively). Other taxa entrained (in decreasing order of abundance) were *Gobiosoma* spp., pinfish, Atlantic menhaden, *Penaeus* spp., portunid megalops, and silver perch. Minor taxa comprised an additional 3.2% of the total number of organisms.

Ten taxa accounted for 95.3% of the total larval organisms collected in impingement samples during 1996 (Table 2.2). The dominant species was spot (40.3%). Most of the ten most abundant species have dominated the larval impingement catch each year since 1984. The cumulative density of organisms collected in entrainment samples increased slightly from 1995 while the total number of organisms collected in larval impingement samples decreased (Tables 2.1 and 2.2; CP&L 1996).

Of the 80 taxa collected, 10 taxa accounted for 96.9% of the total number of organisms collected in J/A impingement samples during 1996 (Table 2.3). Bay anchovy was the most numerous species impinged accounting for 78.6% of the total number impinged during 1996. Prior to intake modifications in 1983, Atlantic menhaden had numerically dominated J/A impingement (CP&L 1980a, 1980b, 1982, 1983). White shrimp, brown shrimp, spot, Atlantic menhaden, blue crab, croaker, star drum, blackcheek tonguefish, and weakfish combined accounted for an additional 18.3% of the total number collected. These ten most abundant taxa comprised 80.2% of the total weight collected during impingement sampling. Other taxa that contributed significantly to the biomass collected during J/A impingement sampling were Atlantic cutlassfish (84.4 kg), pinfish (10.6 kg), Atlantic stingray (10.5 kg), shrimp eel (9.2 kg), and spotted hake (8.5 kg). The total number of organisms collected in J/A impingement samples increased substantially in 1996 compared to 1995 (Table 2.3; CP&L 1996). This was primarily the result of a 129% increase in the number of bay anchovy collected during 1996.

2.3.2 Seasonality and Abundance

The seasonality for selected entrained species in 1996 was similar to those observed in previous years and corresponded to the seasonalities of larval fish in the estuary (Tables 2.4 and 2.5; CP&L 1994). Peaks of abundance in entrainment can be influenced by operating screens without fine mesh, increasing or decreasing the flow of cooling water as determined by plant operational needs, and/or sampling frequency.

The typical winter and summer periods of abundance observed during 1996 in the entrainment program were also observed in the larval impingement program (Table 2.6). Atlantic menhaden, spot, and brown shrimp--all ocean-spawned species--were abundant during the winter and spring months. Croaker were most abundant during the fall. During the late spring and summer, ocean-spawned species (such as pink and white shrimp) and estuarine-spawned species spring and summer, ocean-spawned species (such as pink and white shrimp) and estuarine-spawned species (such as anchovy and *Gobiosoma* spp.) were abundant. The periods of maximum abundance for portunid megalops occurred during the summer and fall.

Peak densities of most of the selected species collected during J/A impingement sampling were associated with the recruitment of individuals too small to be excluded by the diversion structure. Bay anchovy was most abundant during March, April, and December (Table 2.7). The peak density of croaker occurred in June. The relatively small modal length of croaker collected during June indicates that the majority of these individuals were young-of-the-year recruits (Table 2.8). The density of brown shrimp also peaked in June. Peak densities of white and pink shrimp occurred in September. The relatively small size of these shrimp and their respective seasonalities suggest that most penaeid shrimp were recruited to the intake canal as postlarvae. The blue crab was abundant during spring, summer, and fall with peak density occurring during June.

Atlantic menhaden that were abundant during March were yearlings that may have overwintered in the intake canal since there were relatively few damaged diversion screens (Tables 2.7 and 2.8). Previous studies have indicated that the intake canal is used as nursery habitat by some species (Copeland, et al. 1974; Birkhead, et al. 1979). Atlantic menhaden collected in June were young-of-the-year fish as evidenced by their relatively small modal lengths. The peak density of spot occurred during May at which time the majority of fish collected were young-of-the-year. The relatively large modal length of spot collected in June along with a relatively high density indicated that some larger individuals were allowed into the intake canal during a period of damaged diversion screens. The size structure of spot collected during J/A impingement sampling subsequently shifted back to smaller individuals the following month as the number of damaged diversion screens decreased.

Installation of the diversion structure has resulted in a decline in the impingement densities of most J/A organisms. Results of time-series analysis indicated that total organisms and seven of the selected taxa exhibited significant decreases in impingement densities over the study period (Table 2.9). Atlantic menhaden exhibited the greatest decline in impingement density (Figure 2.1). Time-series analysis of bay anchovy and brown shrimp data indicated a nonsignificant trends in the densities of these two taxa impinged over the study period. White shrimp was the only species which exhibited a significant increase in density over the study period (Table 2.9 and Figure 2.2). The trend was most likely a result of a natural increase in white shrimp populations in the Cape Fear Estuary. Previous studies have shown that significant increases in the white shrimp population in Walden Creek coincide with increases in impingement of this species (CP&L 1994). Postlarval shrimp too small to be excluded by the diversion structure successfully recruit to the intake canal and used it as nursery habitat and were subsequently impinged (Birkhead et al. 1979; Copeland et al. 1979; CP&L 1991).

2.3.3 Flow Rates

The amount of water pumped through the plant may affect the number and weight of organisms impinged and entrained. Monthly intake volumes during 1996 ranged from 65.7 million m^3 in February to 168.2 million m^3 in August (Figure 2.3). The mean monthly volume during 1996 was higher than the means of previous years including the period 1977-1982 when there were less stringent flow-minimization requirements. The greater monthly volumes during 1996 were a result of the significantly reduced time required for outages. Low monthly volumes during February and October were due to the scheduled refueling outages.

2.3.4 Fine-Mesh Screens

Studies have shown that the operation of three fine-mesh screens per unit versus no fine-mesh screens reduces the total mean density of entrained organisms by 61% (CP&L 1989). In 1996, entrainment and larval impingement rates were summed to find the total number of larvae affected. The percent effectiveness (how successfully the organisms were kept from being entrained) of fine-mesh screens was calculated as the ratio between the larval impingement rate and the total number (entrainment plus larval impingement) affected for each sampling trip (Table 2.10). The overall effectiveness for total organisms ranged from 2% to 56% when data from all trips were analyzed. The variability of effectiveness was likely influenced by species composition and seasonality.

2.3.5 Survival Estimates

Survival was determined for selected size classes of the dominant organisms that have been impinged at the BNP in past years (CP&L 1985a, 1986, 1987, 1988). Screens were operated on slow-screen rotation speed (75 cm/min) for most sampling dates in 1996. Survival estimates were calculated using survival rates determined during previous studies for slow-screen rotation (CP&L 1988).

Six of the ten most impinged larvae were previously tested for survival (Table 2.11). These six taxa accounted for about 86% of the total larval impingement catch. Survival during slow-screen rotation ranged from 86.3% for portunid megalops to 0% for Atlantic menhaden. *Anchoa* spp. (≥ 13 mm), which were not considered commercially or recreationally important, were not included in the total survival estimate. Estimates indicated that approximately 18% of these selected larval species impinged during slow-screen rotation, excluding *Anchoa* spp. (≥ 13 mm), were returned to the estuary alive. The overall larval survival rate was down from 1995 (39%) due to the decrease in the number of larval shrimp and portunid megalops impinged during 1996. Both taxa exhibit good survival rates.

Six taxa of the ten most impinged J/A organisms were previously tested for survival on slow-screen rotation (Table 2.12). These taxa accounted for 95.4% of the total number collected and 75.6% of the total weight collected. Excluding bay anchovy, survival during slow-screen rotation ranged from 53.1% for croaker to 92.1% for blue crabs. The most valuable commercial species (shrimp and blue crabs) comprised 40.1% of the total impingement catch by weight and exhibited survival rates ranging from 86.5% to 92.1%. Survival estimates indicated that 65.9% of the total number and 55.3% of the total weight of the selected J/A organisms impinged, excluding bay anchovy, were returned alive to the estuary during slow-screen rotation.

2.4 Summary and Conclusions

Seasonality of organisms and the dominant species collected in the 1996 entrainment program were similar to previous years with spot accounting for 39% of all organisms collected. Impingement catches of larvae were dominated by croaker representing approximately 40%. Based on survival estimates data, approximately 18% of selected larval species impinged during slow-screen rotation (excluding *Anchoa* spp. ≥ 13 mm) were returned alive to the estuary. The total mean density of organisms collected in entrainment sampling increased slightly from that collected in 1995. The total number of larval organisms collected in impingement sampling decreased from the 1995 values. By using fine-mesh screens, entrainment was reduced by approximately 11% with a range of 3% to 29% depending upon taxa in 1996. Differences in species composition and seasonalities caused substantial variability in the effectiveness of the fine-mesh screens.

The 1996 juvenile and adult impingement catch was numerically dominated by bay anchovy as has been the case since the completion of the diversion structure in 1983. Prior to 1983, Atlantic menhaden was numerically dominant. Bay anchovy, blue crab, and penaeid shrimp, dominated the J/A impingement catch by weight during 1996. Prior to 1983, larger finfish such as Atlantic menhaden, spot, and croaker comprised the majority of the total weight impinged. Data collected during 1996 continued to show a shift towards impingement of smaller individuals for most of the selected species as a result of the construction of the diversion structure and the use of fine-mesh screens. This is important since it is the larger individuals which comprise the reproducing members of the population. Based on survival estimates, approximately 66% of the total number and 55% of the total weight of the selected organisms, excluding bay anchovy, were returned alive to the estuary. Greater than 90% of the brown shrimp and blue crabs and approximately 87% of the pink and white shrimp were returned alive to the estuary. These were the most valuable commercial species. Results of time-series analysis on 19 years of data indicated significant reductions in the impingement of larger fish and shellfish as a result of the diversion structure. Eight out of eleven selected taxa, including total organisms, exhibited significant decreases in impingement densities over the study period. The impingement density of juvenile and adult Atlantic menhaden exhibited the greatest decline.

Modifications made to the Brunswick Nuclear Plant intake continued to be effective in reducing the number of organisms affected by the withdrawal of cooling water from the Cape Fear Estuary. The diversion structure excluded most large organisms. A substantial percentage of the larval, juvenile, and adult organisms impinged were returned alive to the estuary by using fine-mesh traveling screens and the fish return system.

and 12 days

Table 2.1 Cumulative density (No./1000 m^3) and percent of total for fish, penaeid shrimp, and portunid megalops collected during entrainment sampling at the BNP during 1995 and 1996 (based on ranking for 1996).

Taxon	1995 Cumulative+ density	1995 Percent	1996 Cumulative+ density	1996 Percent
Spot	4,715	40.6	4,812	39.0
Croaker	1,737	15.0	1,818	14.7
Anchoa spp. (< 13 mm)	596	5.1	1,312	10.6
Anchoa spp. (≥ 13 mm)	1,210	10.4	1,092	8.8
Gobiosoma spp.	1,101	9.5	1,040	8.4
Pinfish	151	1.3	681	5.5
Atlantic menhaden	337	2.9	414	3.4
Penaeus spp.	509	4.4	404	3.3
Portunid megalops	400	3.5	255	2.1
Silver perch	35	0.3	123	1.0
Other taxa	653	5.6	400	3.2
Total	**11,603**	**100.0**	**12,351**	**100.0**

+ Cumulative density is the sum of the twelve sampling-day densities.

⇒ mean day density · 365 · daily flow

Table 2.2 **Total number of selected taxa estimated by larval impingement sampling at the BNP during 1996, ranked by percent.**

2.6

no / a

Taxon	Total number⁺	Percent	
Croaker	2.8×10^6 in 12 days	40.3	85 mil
Spot	1.6×10^6	22.6	
Anchoa spp. (≥13 mm)	8.2×10^5	11.9	
Atlantic menhaden	2.8×10^5	4.1	
Pinfish	2.7×10^5	3.9	
Portunid megalops	2.3×10^5	3.4	
Anchoa spp. (< 13 mm)	1.9×10^5	2.8	
Penaeus spp.	1.8×10^5	2.7	
Gobiosoma spp.	1.7×10^5	2.4	
Tonguefish	8.1×10^4	1.2	
Other taxa	3.3×10^5	4.7	
Total¶	**6.9×10^6**	**100.0**	

⁺Total number is a sum of the twelve sampling-day totals.

¶Total may vary from summation due to rounding of individual taxon.

2.7

Table 2.3 Total number, total weight, and percent of total of the ten most abundant juvenile and adult organisms collected in the BNP impingement samples during 1996.

pink shrimp

Taxon	Number+	Percent¶	Weight (kg)+	Percent¶
Bay anchovy	360,331 in 12 days	78.6	334.3	30.6
White shrimp	49,552	10.8	222.7	20.4
Brown shrimp	12,471	2.7	82.5	7.6
Spot	5,123	1.1	31.2	2.9
Atlantic menhaden	4,258	0.9	30.1	2.8
Blue crab	3,845	0.8	127.1	11.7
Croaker	3,727	0.8	21.8	2.0
Star drum	2,350	0.5	9.8	0.9
Blackcheek tonguefish	1,598	0.4	6.8	0.6
Weakfish	1,364	0.3	7.6	0.7
Other taxa	13,559	3.0	217.0	19.9
Total	**458,178**		**1,090.9**	

+Numbers and weights are sums of the twelve sampling day totals.

¶Percentages may not add up due to rounding.

only did once a month

Table 2.4 Entrainment densities (mean no./1000 m³ per sampling day) of selected taxa at the BNP during 1996.

larvae

Month	Total organisms	Croaker	Atlantic menhaden	*Penaeus* spp.	Spot	Anchovies	*Gobiosoma* spp.	Portunid megalops
Jan	**74.89**	21.81	0	2.81	31.01	13.29	0	0
Feb	**1,454.22**	399.54	7.90	0	946.11	55.16	0	0
Mar	**5,179.01**	220.71	351.20	10.55	3,726.13	159.20	0	0
Apr	**333.24**	14.16	54.54	11.75	105.83	126.95	0	0
May	**1,719.24**	0	0	8.75	0	1,020.45	497.11	0
Jun	**964.59**	0	0	14.06	2.78	419.38	483.64	2.86
Jul	**891.47**	0	0	228.14	0	422.82	46.92	58.21
Aug	**197.35**	0	0	40.39	0	121.30	9.14	7.48
Sep	**48.87**	0	0	12.21	0	30.31	0	0
Oct	**543.62**	477.48	0	14.88	0	24.37	2.92	15.00
Nov	**819.84**	585.40	0	60.82	0	7.13	0	155.36
Dec	**124.73**	99.08	0	2.96	0	3.29	0	16.12

Sum 1818 (table 2.7)

Larvae

Table 2.5 Entrainment rates (million per sampling day) of selected taxa at the BNP during 1996.

calculated with 2.4

daily

Month	Volume (10^6 m^3)	Total organisms	Croaker	Atlantic menhaden	*Penaeus* spp.	Spot	Anchovies	*Gobiosoma* spp.	Portunid megalops
Jan	3.597	**0.269**	0.078	0	0	0.112	0.048	0	0
Feb	1.798	**2.615**	0.718	0.014	0	1.701	0.099	0	0
Mar	4.512	**23.368**	0.996	1.585	0.048	16.812	6.718	0	0
Apr	5.343	**1.794**	0.076	0.294	0.063	0.570	0.683	0	0
May	5.383	**9.255**	0	0	0.047	0	5.493	2.676	0
Jun	5.383	**5.192**	0	0	0.076	0.015	2.258	2.603	0.015
Jul	5.297	**4.722**	0	0	1.208	0	2.240	0.249	0.308
Aug	5.701	**1.125**	0	0	0.230	0	0.692	0.052	0.043
Sep	4.019	**0.196**	0	0	0.049	0	0.122	0	0
Oct	2.692	**1.463**	1.285	0	0.040	0	0.066	0	0.040
Nov	5.383	**4.413**	3.151	0	0.327	0	0.038	0	0.836
Dec	4.512	**0.563**	0.447	0	0.013	0	0.015	0	0.078

(Table 2.4) (2.5) * (2.5)

no/1000 - day · Volume/day = losses

* in that month

Table 2.6 Total number of selected taxa estimated by monthly samples of larval impingement at the BNP during 1996.

2.2

Month	Total organisms	Croaker	Atlantic menhaden	*Penaeus* spp.	Spot	Anchovies	*Gobiosoma* spp.	Portunid megalops
Jan	**260,928**	65,664	8,640	0	123,840	40,320	576	0
Feb	**502,416**	233,424	17,568	0	160,848	19,728	0	0
Mar	**1,783,584**	182,304	198,432	2,880	1,084,176	47,664	0	0
Apr	**408,960**	16,128	55,728	128,160	181,152	13,392	0	576
May	**244,224**	17,280	0	10,655	2,880	108,288	43,056	16,128
Jun	**482,688**	0	0	8,064	0	316,800	76,608	5,184
Jul	**538,128**	0	0	9,216	0	298,944	40,608	69,264
Aug	**24,480**	0	0	8,784	0	720	432	13,248
Sep	**148,176**	288	0	1,584	0	124,416	2,304	1,440
Oct	**1,868,400**	1,787,760	0	10,944	0	25,344	1,728	23,648
Nov	**368,208**	293,760	0	2,592	0	8,928	288	54,288
Dec	**253,296**	182,448	144	144	1,584	7,344	0	45,936

Table 2.7 Juvenile and adult impingement densities (No./million m^3 of water entrained during each 24-hour sampling period) for selected species+ and the number of damaged diversion screens per month at the BNP during 1996.

2.3

Month	Bay anchovy	Atlantic menhaden	Spot	Croaker	White shrimp	Brown shrimp	Pink shrimp	Blue crab	Damaged screens
Jan	1,104.7	5.5	80.9	6.9	16.2	0	0	1.8	NA¶
Feb	2,309.6	64.5	13.3	5.8	0	0	0	0.6	14
Mar	21,678.7	318.1	94.1	5.0	0.2	0	0	7.1	0
Apr	27,025.1	116.4	17.7	43.9	5.9	34.9	18.2	131.2	14
May	2,939.8	19.5	254.3	63.9	0.2	0.4	3.8	140.2	26
Jun	814.2	260.8	130.8	338.9	0	1,088.9	0	237.7	66
Jul	27.5	21.7	150.3	148.9	165.9	963.4	33.3	66.1	30
Aug	0	6.6	8.5	11.9	593.4	67.4	19.3	18.1	27
Sep	472.0	19.3	66.3	33.9	8,485.6	145.5	165.0	31.6	21
Oct	370.1	87.2	5.8	2.3	330.9	43.6	13.9	147.5	6
Nov	2,512.1	2.4	12.0	12.0	1,012.3	14.4	4.8	129.2	8
Dec	15,939.2	13.9	217.1	38.4	164.8	0	9.6	44.0	0

+Selected species are commercially and recreationally important species which accounted for > 1% of the total catch by number or weight.

¶NA = not available.

Table 2.8 Modal lengths (mm) for selected+ juvenile and adult impingement species¶ collected by month at the BNP during 1996.

Month	Atlantic menhaden	Spot	Croaker	White shrimp	Brown shrimp	Pink shrimp
Jan	75	70	105	90	NC§	NC
Feb	70	70	45	NC	NC	NC
Mar	70	75	75	160	NC	NC
Apr	70	90	55	90,155	41	55,60
May	80	50	55	165	75	110
Jun	50	145	41	NC	95	NC
Jul	100	60	50	105	105	50
Aug	90	60	80	70	90	45
Sep	41	70	60	85	70	65
Oct	65	85	41,145	125	80	65
Nov	70	65	45,50	90	80	65,70
Dec	75	70	60	120	NC	80

+Selected species are commercially and recreationally important species which accounted for greater than 1% of the total catch by number or weight.

¶Fish ≥ 41 mm and crabs ≥ 25 mm.

§NC= None Collected.

Table 2.9 **Time-series analysis of BNP juvenile and adult impingement data indicating trends in density from January 1977 through December 1996.**

Taxon	Trend+	Slope	R^2
Atlantic menhaden	—***	—0.00055	0.97
Weakfish	—***	—0.00030	0.97
Blue crabs	—***	—0.00030	0.96
Spot	—***	—0.00028	0.97
Croaker	—***	—0.00023	0.96
Southern flounder	—***	—0.00018	0.96
Pink shrimp	—***	—0.00013	0.96
White shrimp	+***	—0.00033	0.98
Bay anchovy	NS		
Brown shrimp	NS		
Total organisms	—***	**—0.00016**	**0.96**

+Trends are explained with the following notation:

NS = P > 0.05
* = 0.01 < P ≤ 0.05
** = 0.001 < P ≤ 0.01
*** = P ≤ 0.001
+ = Increasing trend
— = Decreasing trend

R^2 = Amount of variation explained by the dependent variable in the time-series model.

Table 2.10 Percent effectiveness of fine-mesh screens in reducing the number of selected taxa affected by entrainment per sampling day at the BNP during 1996.

Month	Total organisms	Croaker	Atlantic menhaden	*Penaeus* spp.	Spot	Anchovies	*Gobiosoma* spp.	Portunid megalops
Jan	**49**	46	100	NP+	53	46	100	NP
Feb	**16**	25	56	NP	9	17	NP	NP
Mar	**7**	15	11	6	6	6	NP	NP
Apr	**19**	18	16	67	24	2	NP	100
May	**3**	100	NP	18	100	2	2	100
Jun	**9**	NP	NP	10	0	12	3	26
Jul	**10**	NP	NP	1	NP	12	14	18
Aug	**2**	NP	NP	4	NP	0	1	24
Sep	**4**	100	NP	3	NP	50	100	100
Oct	**56**	58	NP	21	NP	28	100	41
Nov	**8**	9	NP	1	NP	19	100	6
Dec	**31**	29	100	1	100	33	NP	37
Annual	**11**	**29**	**13**	**8**	**7**	**8**	**3**	**15**

+NP = Not Present

Table 2.11 Estimated number and percent survival of selected larval organisms collected during impingement sampling at the BNP during 1996.

Taxon	Number collected	Percent survival[+]
Spot	1.6×10^6	9.0
Croaker	2.8×10^6	14.4
Anchoa spp. (≥ 13 mm)	8.2×10^5	0.3
Penaeus spp.	1.8×10^5	80.3
Portunid megalops	2.3×10^5	86.3
Atlantic menhaden	2.8×10^5	0.0
Total[¶]	**5.1×10^6**	
Percent survival		**17.5**

[+]Reference: CP&L 1988 (Slow-screen rotation).

[¶]Selected species excluding *Anchoa* spp. (≥ 13 mm).

Table 2.12 Estimated number, weight, and percent survival of selected juvenile and adult organisms collected during impingement sampling at the BNP during 1996.

Taxon	Number collected	Percent survival+	Weight collected	Percent survival+
Bay anchovy	360,331	1.1	334.3	1.1
Shrimp (pink and white)	50,807	86.5	225.0	86.5
Brown shrimp	12,471	90.7	82.5	90.7
Blue crabs	4,676	92.1	129.7	92.1
Spot	5,123	57.1	31.2	57.1
Croaker	3,727	53.1	21.8	53.1
Percent survival (Selected species)		**14.9% by number**		**38.7% by weight**
Percent survival (Selected species excluding bay anchovy)		**65.9% by number**		**55.3% by weight**

+Reference: CP&L 1988 (Slow-screen rotation).

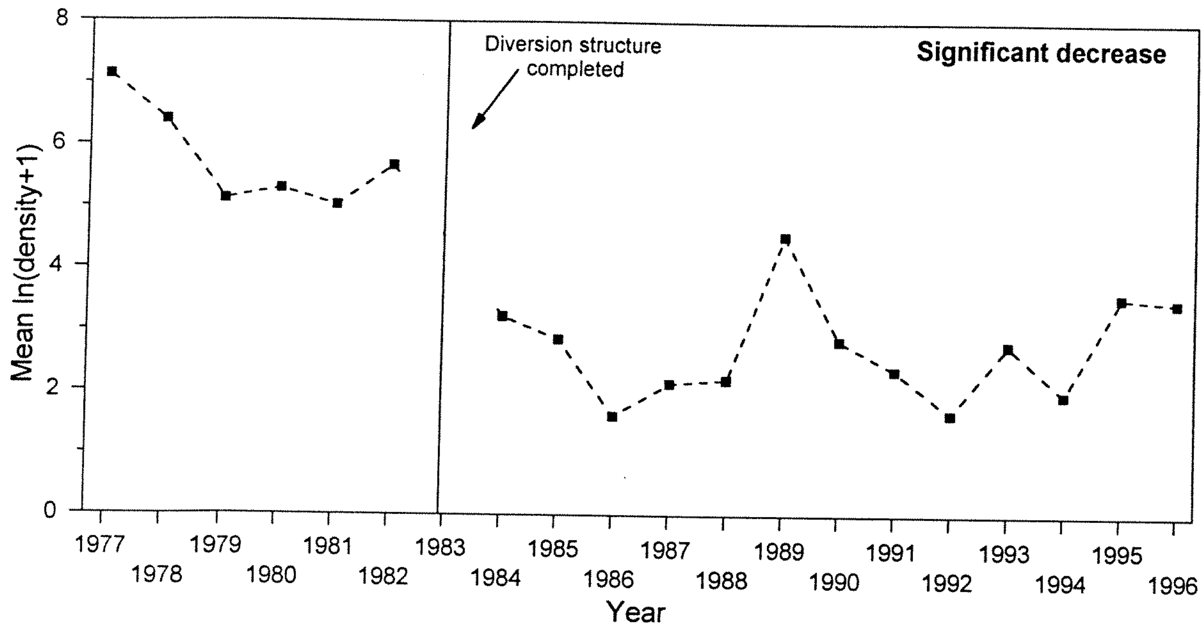

Figure 2.1 Time-series analysis of juvenile and adult Atlantic menhaden data collected during impingement sampling at the BNP from 1977 through 1996.

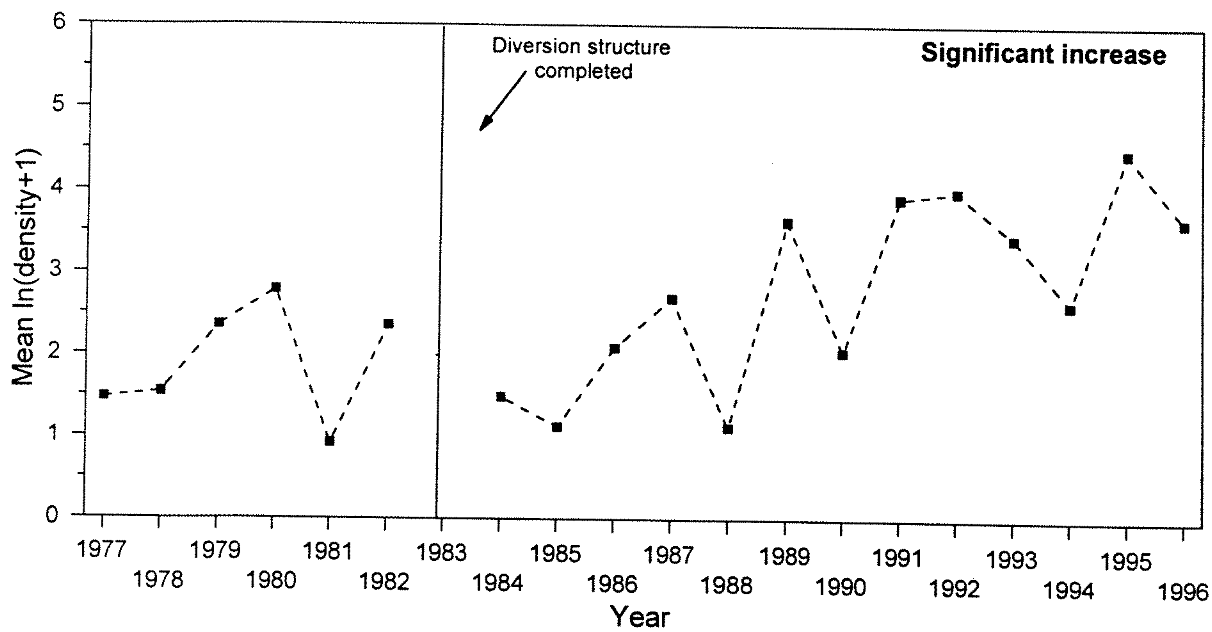

Figure 2.2 Time-series analysis of juvenile and adult White shrimp data collected during impingement sampling at the BNP from 1977 through 1996.

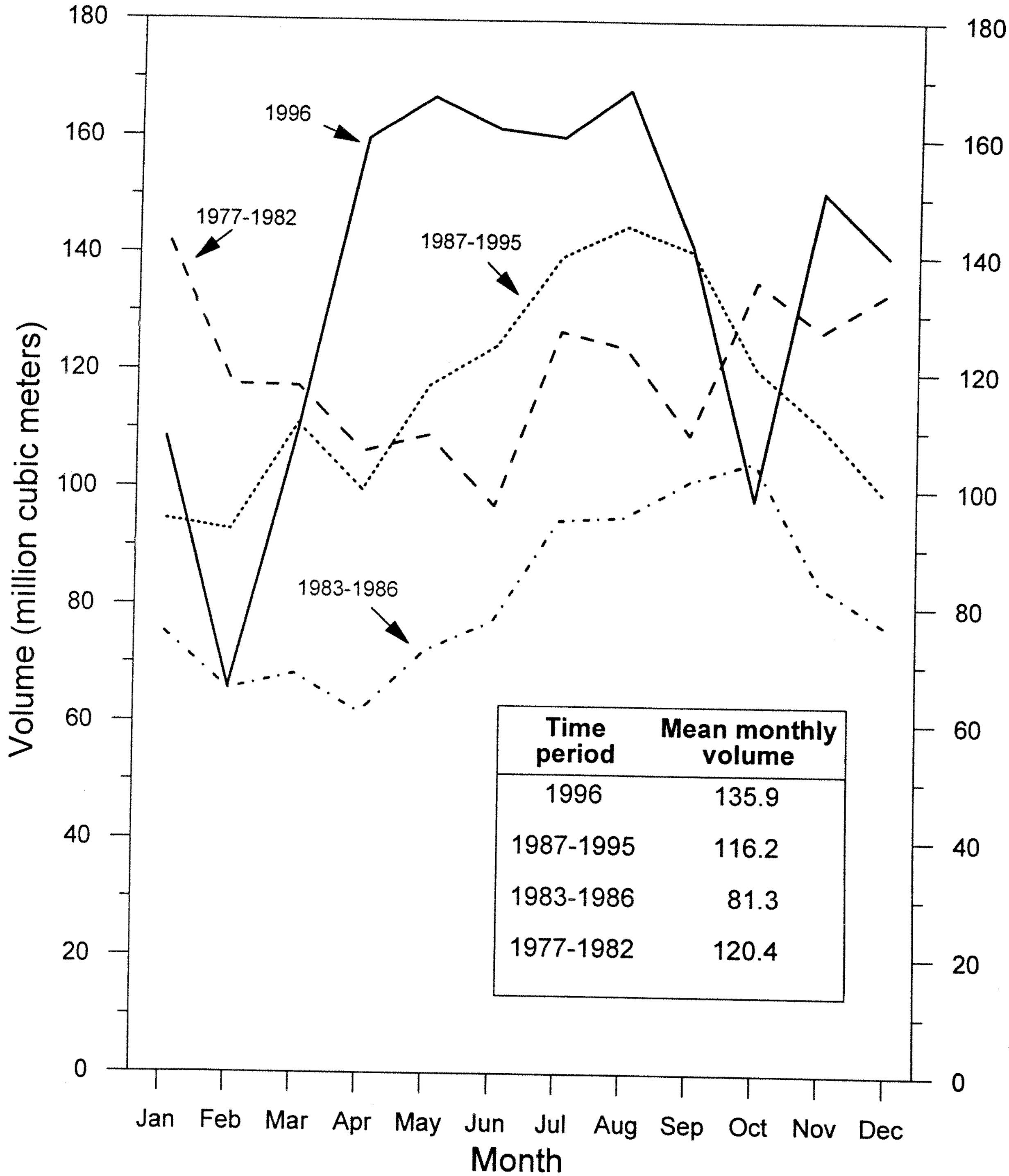

Figure 2.3 **Monthly flow of water pumped at the Brunswick Nuclear Plant from 1977 through 1996.**

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